Quantity-Distance Determination
For
Third Generation Aircraft Shelters (TGAS)

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Introduction:

Hazardous fragment clear zones for hardened aircraft shelters severely restrict combat operations. These clear zones are derived from data produced by the Distant Runner test series. The two Distant Runner tests which drive this criteria demonstrated catastrophic failure of the shelters loaded with 2, 292 pounds and 9,168 pounds of explosives. Hazardous fragment clear zones must be applied when shelters contain more than 110 pounds of explosives.

We felt that if we could determine the explosive weight at which incipient failure occurs, we could significantly reduce the required dear zones. Analysis of third generation hardened aircraft shelters revealed that catastrophic failure would not occur with explosives weights up to 1,000 pounds. Since 1,000 pounds of explosives in a shelter is an operationally viable explosives weight the Explosives Hazard Reduction Program sponsored the test program described in this paper.

Project Definition:

A project team was formed by ASC YOCO which included the Weapons Laboratory (WL /NTE) and the University of New Mexico, New Mexico Engineering search Institute (NMERI), to determine the zero dear zone for the TGAS. The project was divided into several phases. These were:

Phase 1: A state of-the-art review of TGAS Q-D research. The purpose of this was to maximize the probability of successfully identifying viable Q-D criteria with a limited number of calculations to be conducted in Phase 2. All available existing information (theoretical, calculational, and experimental) which related to the TGAS Q-D problem were considered in the process of defining the calculations to be performed. This included existing information such as reports from the Defense Nuclear Agency (DNA) Distant Runner program, as well as results from programs such as the scaled studies conducted at Southwest Research Institute (SwRI), the US-Norwegian shelter design project, and investigations conducted by the Department of Defense Explosives Safety Board (DDESB). The end product of this phase was a data package which contained information on all tests and calculations which were determined by NMERI Hardened Aircraft Shelter (HAS) experts to be relevant to the TGAS Q-D problem. The next step was to assess the data package with respect to the zero Q-D problem. This involved attempts to bound the zero Q-D NEW by looking for the maximum NEW with acceptable structural response (no debris ejected from the external surface of the TGAS concrete arch) and the minimum NEW with unacceptable response. The assessment also identified Q-D trends related to the location of charges in the TGAS as well as distribution of munitions within charge stacks.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **AUG 1994**	2. REPORT TYPE	3. DATES COVERED **00-00-1994 to 00-00-1994**

4. TITLE AND SUBTITLE **Quantity-Distance Determination for Third Generation Aircraft Shelters (TGAS)**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **ASC / YOCO (EHR),Eglin AFB,FL,32542**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM000767. Proceedings of the Twenty-Sixth DoD Explosives Safety Seminar Held in Miami, FL on 16-18 August 1994.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

Phase 2: Involved the calculational work. The first step was to use the previous results to define the calculations to be performed. This involved the determination of TGAS structural response to various explosive charge distributions via numerical modeling. Loading the TGAS structure as a function of space and time were calculated with finite difference fluid dynamic modeling programs (hydrocodes). These loads were used as input for finite element calculations of the actual TGAS structural response. The results of these calculations were analyzed with respect to zero Q-D requirements to determine if the given explosives configuration was acceptable or not. Due to limited project resources, the calculations were limited to two dimensional models only. The hydrocode calculations were initially performed with the NMERI GUSH program. The results of the GUSH calculations were then used to develop more refined models for the more costly WL HULL or SHARC program. The finite element calculations were done with the WL SAM-SON program. SAMSON calculated displacements for the TGAS concrete arch, floor, and foundation structures, as well as adjacent soil. These displacements were subsequently analyzed with respect to zero Q-D concerns.

This effort[1] predicted that the MK 83 (500 pounds explosive weight) was below the zero Q-D calculations and the MK 84 (1000 Pounds explosives weight) was near the zero Q-D criterion. The shelter should contain the detonation but would be severely damaged and unsafe to enter after the test. The next step was to conduct experiments to establish confidence in the predictions.

Phase 3: Testing. Due to limited funds it was not possible to conduct scale experiments. However, a full size TGAS was available. This structure was a full-size 3rd generation aircraft shelter similar to those constructed in the European and Pacific theaters. The shelter was constructed at the Hill Air Force Base UTTR in 1986 for a program which evaluated its vulnerability to 30 mm aircraft cannon projectiles. The third generation aircraft shelter is a double radius arch with an interior clear span of 21.6 The arch cross section consists of a 3.2 mm thick, 356 mm deep, double corrugated metal arch overlaid with reinforced concrete. The thickness of the concrete overlay varies from 457 to 813 mm depending on which point on the corrugated metal section it is measured. The reinforced concrete rear wall is 610 mm thick including a 3.2 mm thick steel spall plate on the inside surface. The two part reinforced concrete front doors are supported by a structural steel space frame. The length of the arch portion of the shelter is 36.6 m. This length does not include the jet engine exhaust port structure at the rear of the shelter, or the front door and its supporting space frame. The front door is located at the southern end of the shelter constructed at the UTTR test site. The weapon used for the test was a 2000 pound, low drag, MK 84, GP bomb. The MK 84 contains 430 kg of Tritonal explosives, and its case weighs 420 kg. The outside diameter of the bomb is 45.72 cm. Its overall length, minus the nose fuse and tail fin assemblies, is 241.3 cm. The bomb was positioned in the center of the shelter 1.52 m above the shelter floor. Figure 1 shows the location of the bomb in the shelter The longitudinal axis of the bomb was parallel to the longitudinal axis of the shelter. The bomb was detonated using 1.02 kg of C-4 explosives and two RP-1 modified detonators placed in the nose fuze cavity.

Figure l. Bomb Placement

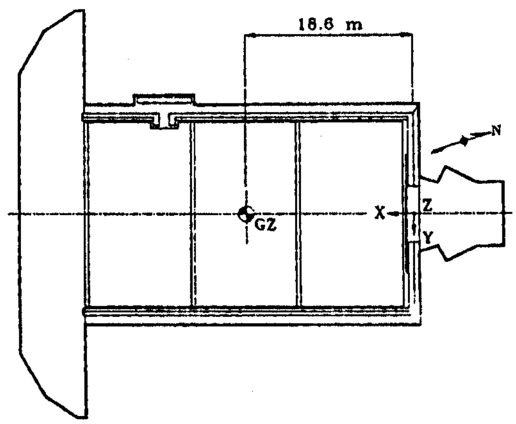

Figure 1. Bomb Placement

Debris was catalogued on all sides of the shelter[2]. Because of the preexisting damage to the West side of the HAS, debris hazard determination was made from debris on the East side. It was judged to be more representative. Initial debris recovery included a sampling of debris from ground zero (GZ) to 150 meters and 100 percent recovery from 150 meters outward.

Later analysis of this debris indicated that the hazardous fragment distance was less than 150 meters and a subsequent debris collection was conducted from 75 to 150 meters.

Debris Analysis:

Expanded debris collection permitted development of a methodology[3] to produce a realistic interpretation of the hazardous fragment distance.

Hazardous debris from the East side of the shelter is shown in figure 2. The debris fell primarily within a 60° cone perpendicular to the side of the HAS. A histogram of the debris, figure 3, shows that most of the debris (84.8%) fell within an arc ±15° from a line drawn from GZ perpendicular to the side of the shelter. It is felt that bounding the debris by ±15° creates a conservative approach when using an averaging technique.

The hazardous fragment distance was determined by bounding the data by the $\pm 15^0$ angle and using the following technique to calculate hazardous fragment distance (more than one hazardous fragment per 600 ft^2).

Figure 2. Hazardous Debris

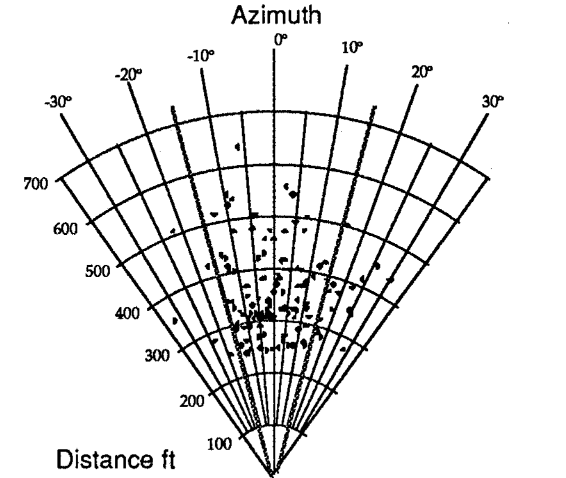

Figure 2. Hazardous Debris

Figure 3. Fragment Histogram

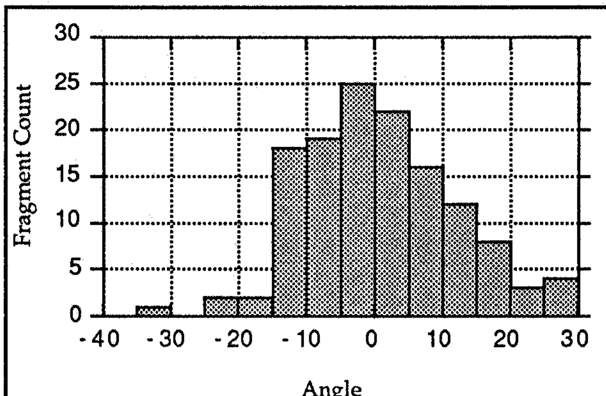

Figure 3. Fragment Histogram

The data was bounded by $\pm 15^0$ which is represented by angle (α in figure 4. A sector of length **d** (100 feet in this analysis) was moved away from GZ in increments of **I** (10 feet in this analysis). The analysis started at distance **a** (250 feet in this analysis, the distance at which 100% debris collection started). At each step, the area of the sector was calculated, the

number of fragments in the sector was counted, and the number of fragments per 600 ft^2 was calculated. This continued until the furthest fragment (distance b) was included in the fragment density calculations. The distance from GZ to the center of the sector is the distance reported for the hazardous fragment density. For example: if the sector length d is 100 feet and the analysis starts at 250 feet. The first calculation will involve the sector from 250 to 350 feet and hazardous fragment density for that sector is recorded as 300 feet.

Figure 4. Methodology

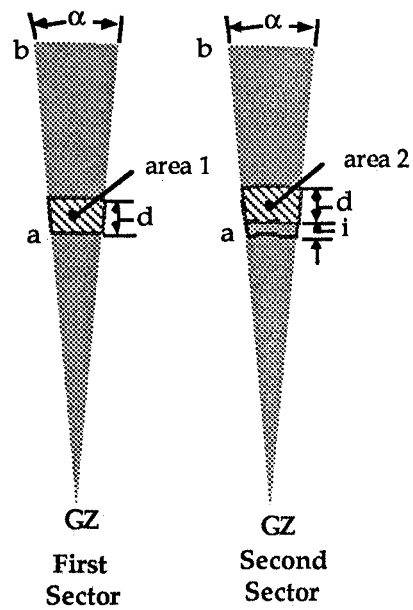

Figure 4. Methodology

Figure 5 is a plot of the hazardous fragment density (fragments per 600 ft^2). The fragment density falls below one fragment per 600 ft2 at 395 feet. Since the distances were measured from the center of the shelter (76.3 feet wide-outside wall to outside wall) the hazardous fragment distance from the outside wall is 395 minus 38 or 357 feet.

Figure 5. Hazardous Fragment Distances From Center Of HAS

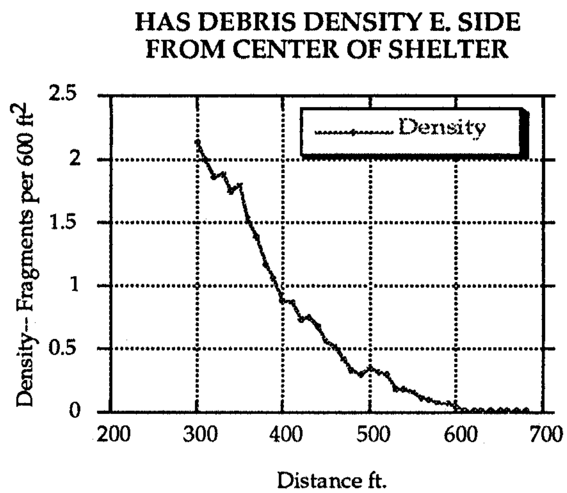

Figure 5. Hazardous Fragment Distances From Center Of HAS

Conclusions:

The hazardous fragment distance from the side of the shelter containing 1000 pounds NEW is 357 feet.

The shelter presents no significant hazardous fragment threat with 500 pounds NEW. This is based on the testing in which MK 83 bombs were detonated at and near the surface of the shelter. And by Q-D determinations made by modeling[1]. Inhabited building distance from the side of a shelter containing 500 pounds NEW is driven by overpressure and is 45 feet[5].

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